REDUCING THE COMMUNICATION COSTS OF A REMOTE MONITORING AND MAINTENANCE SYSTEM FOR AN ENERGY SERVICES COMPANY (ESCo)

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ABSTRACT

Demand-Side Management (DSM) initiatives can result in substantial electricity cost reductions. Energy Service Companies (ESCos) typically perform remote monitoring and maintenance to ensure sustained performance of these DSM initiatives. Mobile network service providers offer the flexibility required to allow an ESCo to monitor DSM initiative that are widely distributed across South Africa. Mismanagement of the communication infrastructure and the potential for excessive data usage threatens the financial feasibility of remote DSM maintenance. Software was developed to promote improved management of this communication infrastructure, and to monitor the accessibility, data usage and other communication vitals automatically and remotely. Optimal management of the communication infrastructure ensures the lowest possible base cost, while prediction based on data usage information allows for predictive maintenance in order to avoid or reduce excessive data costs. This paper presents the process of reducing the communication cost of an ESCo that actively monitors and maintains more than forty DSM initiatives. Improved asset management and automated monitoring resulted in a 73% reduction in the monthly communication costs.

This work was sponsored by HVAC International

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1. INTRODUCTION

When implementing Demand-Side Management (DSM) projects on a mine and industrial plants, Energy Service Companies (ESCos) typically develop specialised control systems that implement DSM strategies. Van Heerden *et al.* [1] and Van Jaarsveld *et al.* [2] describe the development and implementation of such systems. Du Plessis *et al.* [3] showed that remote monitoring and maintenance is vital for sustaining DSM performance and the resulting cost benefit. Furthermore, the overall maintenance process can be optimised by introducing automated diagnostics that span across the industrial system targeted for DSM intervention; the system that implements the DSM strategy; and the performance assessment and reporting system.

This cascade of monitoring, diagnostics and remote maintenance systems creates a complex scheme that is highly reliant on communication infrastructure that facilitates remote maintenance. Interrupted communication impairs the ability of maintenance personnel to assess DSM performance and perform reactive maintenance based on automated diagnostics. This threatens the sustainability of DSM initiatives and could result in lost financial savings. Therefore, to make DSM maintenance financially feasible, the cost of maintenance must be kept well below the potential financial savings produced through sustained DSM performance.

2. BACKGROUND

Blumberg [4] analysed the customer calls of more than twenty service organisations and found that most service requests do not require on-site assistance. According to Blumberg [4], 80% to 90% of software-related difficulties and 10% to 40% of hardware-related difficulties can be corrected with remote assistance. Since the publication of this work in 1982, the opportunities for remote monitoring initiatives have increased, as discussed by Weppenaar *et al.* [5], due to the rapid growth of the information and communication technology field. As mentioned by Yang *et al.* [6], these systems provide large organisations with the ability to collect, store and analyse information from distributed sites.

Du Plessis *et al.* [3] and Du Plessis *et al.* [7] presented the concept for an automated diagnostic system designed to assist an ESCo to maintain the performance of DSM initiatives remotely, and provided the results obtained after implementing this system. Du Plessis *et al.* [8] elaborated on the use of this new system by presenting case studies detailing diagnostics of the DSM strategy of mine water reticulation systems; and cooling auxiliaries on different mines. These works highlighted the contribution of continuous remote maintenance towards sustained DSM performance. Furthermore, the obtained results showed the value of automated diagnostics of the DSM implementation in general; and the DSM strategy in particular. The diagram in Figure 1 shows the complexity of the DSM implementation, the diagnostics system and the communication system that allows for automated diagnostics and remote maintenance.

Hardware components are connected through different networks. The equipment and instrumentation are connected to the Programmable Logic Controller (PLC) and Supervisory Control and Data Acquisition (SCADA) system through an industrial network. The DSM server connects to the PLC and SCADA system via an Ethernet network, and uses an Open Platform Communication (OPC) connection to read values from field instrumentation, and to control industrial equipment according to a specific DSM strategy.

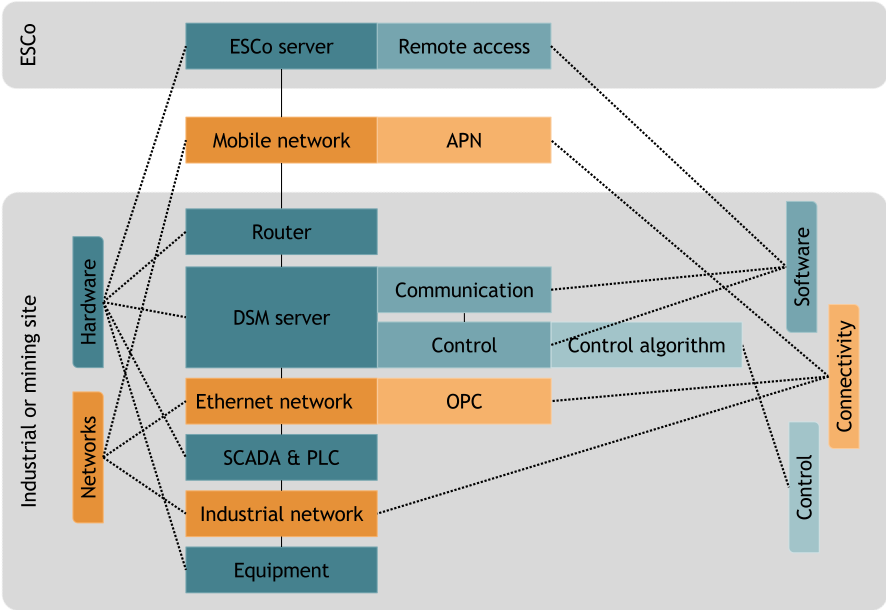

Figure 1: Remote diagnostics and maintenance system (constructed from [3], [7], [8])

A mobile router connects the DSM server to the ESCo server via mobile networks. Mobile networks provide the flexibility required to monitor DSM initiatives that are widely distributed across South Africa [9]. The execution of the DSM strategy is not reliant on this mobile network, yet, the mobile network allows for prompt notification of irregular operation. Furthermore, this mobile network connectivity also allows maintenance personnel to access the DSM server remotely in order to perform corrective maintenance.

Interruptions in mobile network connectivity threaten the sustainability of DSM initiatives. Some geographic areas experience weak or no signal for a specific mobile network service provider, which makes it impractical to use one service provider exclusively. A private Access Point Name (APN) provides a cost effective method for linking Subscriber Identification Module (SIM) cards from different service providers to the same secure network [10]. This private network only facilitates connectivity between SIM cards that are provisioned with access to this APN. Figure 2 shows a private APN facilitating connectivity between SIM cards from different service providers.

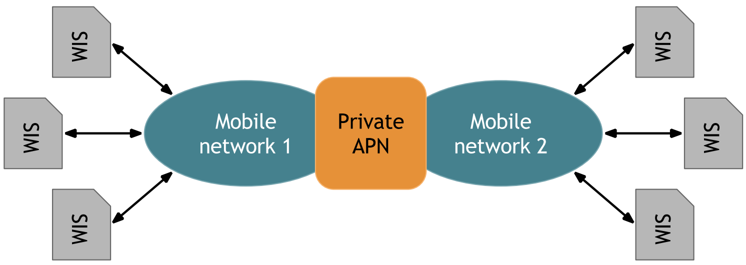

Figure 2: Data flow through an APN

SIM cards are linked to active mobile lines that are procured from mobile service providers on a contract basis, with fixed monthly data allocation. This ensures continuous connectivity and reduces the overhead created by replenishing prepaid lines on a monthly basis. In turn, the APN service provider charges a fixed monthly fee for each mobile line that is provisioned on their APN.

3. MANAGING COMMUNICATION COST

Data contracts are a major contributor to an ESCo's monthly communication bill, illustrating the roll of optimal managing of mobile lines in reducing communication costs. Mismanagement of mobile lines can result in the over-procurement of data contracts. However, optimal management of mobile lines, linked to SIM cards that are distributed across the country has proven to be challenging. Table 1 lists four circumstances that can be avoided or quickly identified through comprehensive management. The table also shows what risk factors are involved for each of these circumstances. The first risk factor indicates the potential for excessive data usage and cost. The second risk factor indicates that the SIM card has become unavailable for use and therefore could result in procurement of unnecessary contracts.

Table 1: Risks associated with mismanagement

Circumstance	*Risk factor* *Data usage*	*Lost SIM*	*Description*
Unnecessary redundancy		X	Routers support failover to a secondary SIM card for areas with weak signal reception. Improved reception on one of the SIM cards voids failover. Secondary SIM card becomes dormant.
Accidental redundancy		X	Secondary router installed although the site already has a router that is not on the asset register.
Offline router		X	Router is broken, removed or disconnected.
Theft or abuse	X	X	Site personnel use a SIM card for personal use.
Malfunction	X		Failed data transmission is mistakenly perceived as successful, resulting in continuous retransmission of the same data.
Malware	X		Certain malware probe the computer network to infect other machines. Probing involves continuous transmission of small data packets that amount to large data transmission on a monthly basis.

Monitoring the cost of communication in general and the cost of individual lines in particular is the starting point to identify excessive data usage. The first option is to use information from the monthly bills to identify overspending based on a predefined budget. A monthly bill can however only be used to identify situations where excessive usage has already occurred. The bill will reflect the data cost of the previous month, or depending on the billing cycle and billing date, the cost of the month before the previous month. To illustrate this, Figure 3 shows the costs generated by a single mobile line over a five-month period in 2013. This figure also shows the cost reflected on the bill for each of these months. The first month shows the normal monthly cost of R 149. During the second month, this cost escalated to R 2 355, and excessive costs continued for the next three months.

If the billing date is set for the last day of every month, it does not allow sufficient time to consolidate the data usage for that specific month. Therefore, the bill received on the tenth day of Month 5 reflected the data cost generated in Month 3. At that stage, Month 4 already produced a similar data usage, which continued for the first ten days of Month 5. This resulted in a total overspend of R 58 185 during this five-month period. Therefore, using monthly bills to monitor communication cost does not significantly reduce the risk of excessive costs.

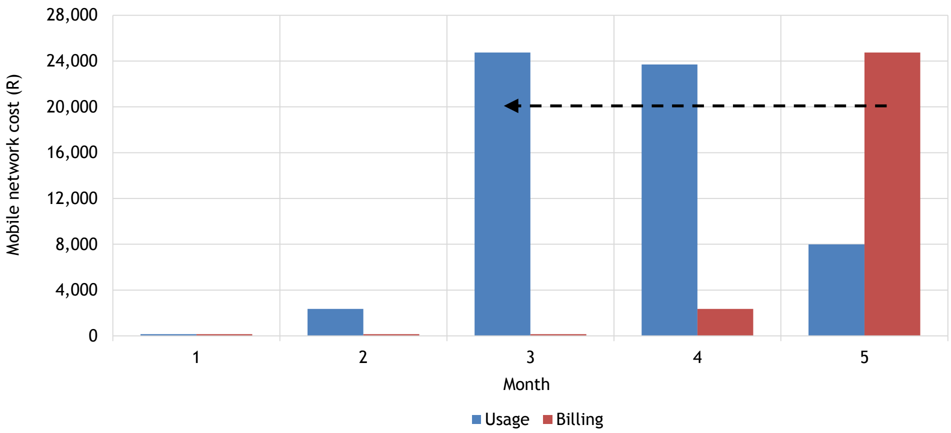

Figure 3: Delay between usage and billing dates

To improve the resolution of data checking, complete data usage reports were requested from the service providers on a weekly basis. These requests were occasionally serviced promptly, but other requests were delayed for up to a week. After escalating these requests week in and week out, it became apparent that this is not a sustainable method to monitor data usage figures. Most service providers grant access to account and billing information using an online portal. These portals allow for manual generation of data usage reports, which ensured that the reports could be generated consistently on a weekly or even daily basis. Importing this data on a daily basis remains a manual process that is prone to human negligence.

4. AUTOMATED MONITORING

Heyns *et al.* [11] emphasised the importance of performing a root cause analysis using appropriate information, before making decisions. Software was developed to request information from routers on a daily or even hourly basis, in order to promote access to the correct information, which allows for prompt reaction to identified risks.

4.1 Asset management

The developed software allows the user to import a detailed subscriber list holding information on the mobile lines registered at each service provider. In addition to this information, the software can import a list that links the private APN Internet Protocol (IP) addresses to the specific mobile line. Table 2 lists the information that is retained in the database of the developed software, and the reason why this information is required.

Table 2: Mobile line and APN information

Information	*Need*
SIM number	Unique serial number of the SIM card used for asset manage
Subscriber number	Unique number used to administrate the contract
Contract type	Indicates the size of the recurring monthly data allowance
Contract expiry date	Date after which a contract can be reviewed
Subscriber status	Indicates weather a subscriber is active or locked
APN IP address	Address used to access the site remotely

The software allows the user to allocate a mobile line or multiple mobile lines to a site or personnel. In extension to this, the mobile line that is allocated to a site might be allocated to different DSM initiatives implemented at that specific site. The software therefore enables administrative personnel to keep an electronic record of SIM card allocations, including the responsible person for each DSM initiative. Furthermore, the software allows maintenance personnel to gain remote access to the onsite DSM server, using the information in Table 2.

4.2 Monthly budgeting

The developed software also allows maintenance personnel to import monthly invoices in order to analyse the actual cost against the budget for individual mobile lines. The aim is not to exceed the fixed monthly contract cost, and therefore this cost is used as the budget for each individual mobile line. Any mobile line that exceeds the budget is highlighting for corrective action. Furthermore, the developed software provides an overview of budget and actual costs for the last year, assisting maintenance personnel to identify mobile lines that exceed the budget on a regular basis.

4.3 Communication checks

The developed software periodically checks the level of communication to all the SIM cards installed in on-site routers. The level of communication is calculated based on the number of successful ping requests sent to each router. This information is then used to calculate an average daily communication level for each router, which is combined to form a monthly profile. Personnel use this profile as an indication of the stability of the connection to each installed router. Additional information about the communication channel is obtained by sending Hypertext Transfer Protocol (HTTP) requests to the router. The information that can be requested from the router includes the signal level, the current active SIM (primary or secondary) and router serial number.

Furthermore, the software initiates Unstructured Supplementary Service Data (USSD) commands on the router in order to query the data balance of the mobile line linked to the installed SIM card. This data usage is then represented as a data usage profile from the start of the current billing cycle, giving maintenance personnel an indication of the data usage tendencies of each site. The software can provide a snapshot of the latest data usage figures for all mobile lines. A prediction of the total data usage at the end of the current billing period allows the ESCo to benefit from preventative maintenance, as discussed by Vermaak *et al.* [12].

5. IMPLEMENTATION

At the beginning of 2014, the total number of SIM cards used for remote maintenance peaked at 187, with a combined monthly cost of approximately R 50 000. No spare SIM cards were available, therefore requiring a new 24-month data contract every time a new SIM was required. In mid-2014, an investigation was initiated to verify the allocation of all SIM cards.

5.1 Investigation

The list of existing SIM cards and the last known allocation of each SIM card was imported into the developed software database. Figure 4 shows an outline of the investigation process. The first objective was to request a list of SIM cards that have been dormant for more than three consecutive months. This list was imported into the software and all the dormant SIM cards were marked for replacement. As a second objective, 44 personnel SIM cards were verified. The third objective was to verify SIM cards assigned to sites. Remote connections were used to verify 47 of these SIM cards, while 28 SIM cards required site visits for verifications and reinstatement of remote access. Installation records for portable data logger, that require voice contracts for dialup based data transmission, verified the locations of a further 22 SIM cards.

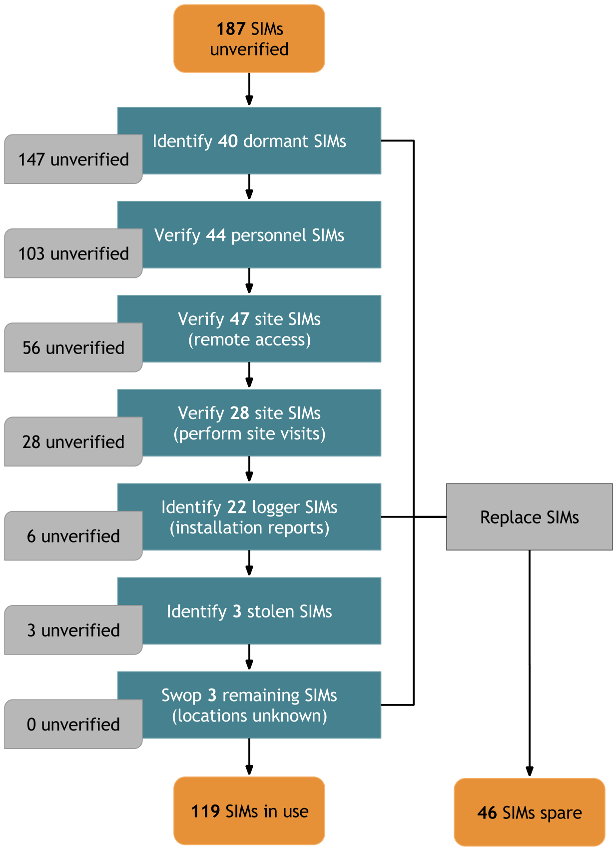

Figure 4: Investigation process

The itemised bills of the six remaining SIM cards were used to identify suspicious activity. Three of these SIM cards showed billing for SMS messages and voice calls to various unknown numbers. Voice calls to the three corresponding mobile lines verified that unauthorised individuals were using the SIM cards. The remaining three SIM cards could not be located and did not show significant data usage; therefore the SIM cards were replaced.

5.2 Automated data collection

This investigation resulted in an updated database of all the SIM cards owned by the ESCo, and a substantial increase in the number of spare SIM cards. The software was configured to start collecting information from all routers that are allocated to sites. Figure 5 shows the overview page of the developed software with a list of DSM initiatives and the responsible personnel. The APN IP address is used to request data from the router and the SIM card remotely. This data is categorised as indicated by the five blocks in Figure 5.

The software shows when communication to a site is lost for prolonged periods and will therefore assist to rectify problems promptly. In addition, the data usage profiles of sites are constructed and allows for reassessment of the contract type and additional bundling. This information is also vital before implementing risk-limiting strategies, in order to prevent necessary interruptions in communication.

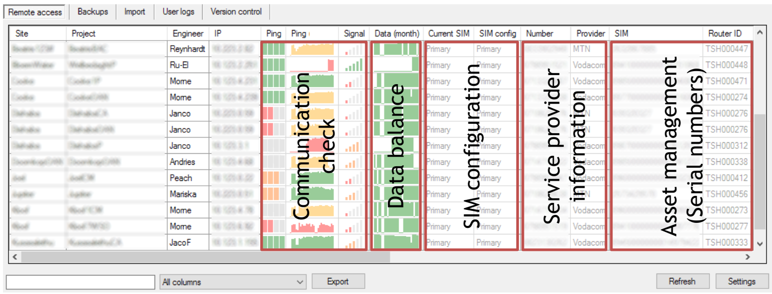

Figure 5: Communication overview on developed software

5.3 Reducing the risk of overspending

The next step was to ensure that the risk of excessive usage is reduced to a minimum. A cost limit is required in order to prevent excessive data costs as discussed in section 3. Mobile network service providers might offer the option to prevent data usage in excess of the allocated monthly data allowance. One of the ESCo's service providers did not provide this same option, however, it offered a cost limit instead. The mobile line is locked once the cost exceeds the budget by more than the elected cost limit amount. A mobile line lock prevents further charges and is only removed at the start of the next billing cycle. Figure 6 shows the maximum cost of six mobile lines with active cost limit of R 100. Line 6 exceeded the limit by up to R 1 500. The service provider stated that the exact cost incurred before the mobile line is locked cannot be guaranteed.

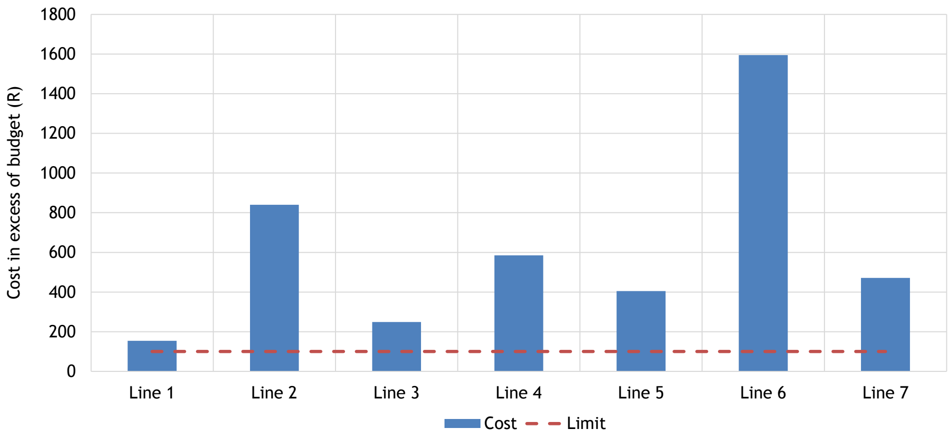

Figure 6: Monthly costs exceeding the cost limit

Although this unguaranteed limiting is not ideal, it was found that only exceptional cases would result in the budget being exceeded by more than R 1 000. Therefore, the risk of excessive costs that compare to the costs presented in section 3 is eliminated. Budget violations are further reduced by actively monitoring the data usage with the developed software. As discussed in Section 4, the automated monitoring system generates a data usage profile and predicts future data usage. This mechanism allows maintenance personnel to identify potential budget violations and take immediate corrective action to prevent or minimise the extent of overspending.

5.4 Reducing the base cost

Following the investigation process, 46 SIM cards became available for reallocation. There is however no need to keep such a large amount of SIM cards as spares. Therefore, a substantial portion of the spare SIM cards was marked for termination upon contract expiry. Base costs can be reduced further by contract upgrades, contract downgrades, and bundle adjustments. The automated monitoring software discussed in Section 4 allows for a data usage profile to be constructed. This profile clearly illustrates the behaviour of the mobile line, which can be analysed in order to determine whether a contract adjustment is required. If the overspending is found to be more expensive than a contract upgrade or a recurring data top-up, the contract is upgraded to minimise overspending. When a mobile line utilises significantly less data than the monthly allocation, a contract downgrade is considered after the contract expires.

6. RESULTS AND DISCUSSION

The implementation process started with a three-month investigation in June 2014. In October 2014, a pilot version of the developed software was implemented and updated with all the verified data. The software started to perform automated data collection. In subsequent months, the functionality of the software was expanded continuously.

6.1 APN cost reduction

Mobile lines could be cancelled immediately after the initial investigation because these contracts were still in place. Early contract termination results in a settlement cost comparable to the outstanding monthly costs until the contract end date. Figure 7 shows the monthly APN cost and the corresponding number of active mobile lines. Although the first mobile line cancellations only took place in May 2015, unnecessary APN subscriptions could be cancelled with a notice period of one month.

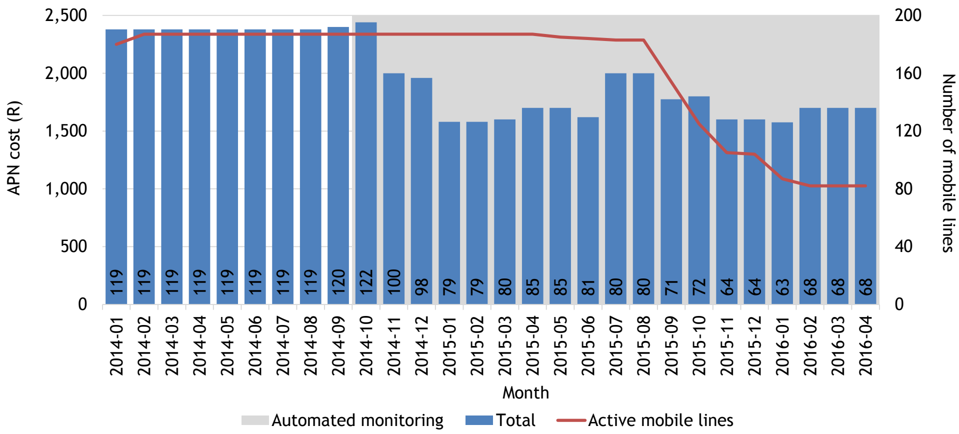

Figure 7: APN subscription cost and number of lines

In November 2014, the first 22 mobile lines were deregistered from the APN as shown in Figure 7. As mobile lines were marked for cancellation, APN registrations were further reduced to a total of 79 in February 2015. The number of APN subscriptions fluctuated over the following months as communication requirements change. An APN tariff increase caused the total cost of the subscriptions to increase in July 2015 even though the number of subscriptions was reduced. Despite this tariff increase, the total monthly APN cost was be reduced from R 2 440 in November 2014 to R 1 700 in April 2016.

6.2 Mobile line base cost reduction

The APN cancellations provided an immediate reduction in cost, but the proposed mobile line cancellations had a much larger potential cost reduction. Figure 8 shows the total monthly mobile line cost starting in January 2014, compared to the budget of each month. The monthly cost is calculated based on the total cost of voice contracts and the total cost of data contracts for the specific month. The bars in the figure also show the number of mobile lines allocated to each of these costs. It is clear that in January 2014, 67% of the costs were generated by 33% of the mobile lines. Many of these voice contracts could be replaced by data contracts, because dialup connections were not used any more.

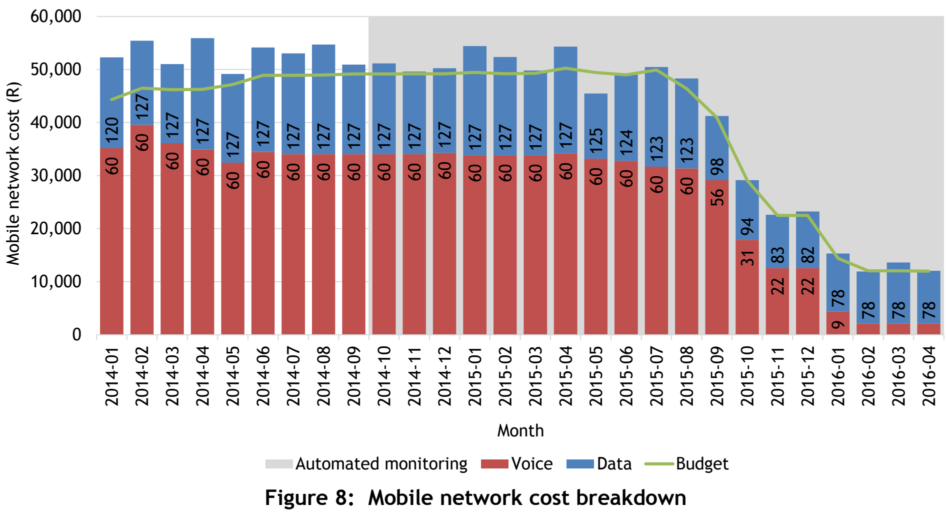

Figure 8: Mobile network cost breakdown

All SIM cards of mobile lines that were marked for cancellation were made unavailable for allocation to sites. Active management reduced the base cost of communication from R 44 324 in January 2014 to R 11 996 in April

2016. This reduction was achieved using the developed software to show the real demand for mobile lines compared to the current asset allocation. This resulted in a decrease in mobile lines from 180 to 82. In addition, expensive voice enabled contracts could be grouped together and replaced with existing data contracts in order to reduce unnecessary costs. The 60 voice enabled contracts were reduced to 4, which expired in June 2016.

6.3 Mobile line overspend reduction

In addition to reducing the base cost, the developed system allowed for better data usage tracking on a daily basis, hence reducing the incidence and severity of overspending. In Figure 8, only three major incidences of overspending occurred. In January 2015, a voice-enabled contract with no data allowance was installed on site in error. The mobile line immediately started to use data at a cost of R 2 per megabyte. The cost escalated and the SIM card was not being actively monitored because it was not allocated to a site. In February 2015, one of the personnel SIM cards was stolen and it was only reported stolen the next day. The thieves generated a bill of R 1 693.19 before the limit lock blocked the SIM card. In May 2015 overspending was identified on a mobile line that was prohibited from exceeding the monthly data allowance. Furthermore, the developed software showed a substantial data balance at the end of the billing period. This contradictory information was as result of a billing error that was rectified on the next bill.

7. CONCLUSION

Effective management of communication infrastructure can minimise the cost of monitoring DSM implementations distributed across the country. Communication costs can contribute considerably to the ongoing DSM maintenance cost and can have a negative impact on the overall financial savings achieved by a DSM initiative. This paper shows how the communication cost of an ESCo can inflate maintenance costs. The cost of communication should therefore be reduced to a minimum in order to ensure cost effective DSM maintenance.

When using a mobile network for communication, mismanagement results in an increased base cost, while sporadic data usage spikes results in costs that exceeds the budget. Software was developed to improve this management process and to increase the resolution at which communication-related information could be retrieved; from a monthly period to an hourly period. By focussing on preventative maintenance procedures, the risk of overspending was significantly reduced.

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